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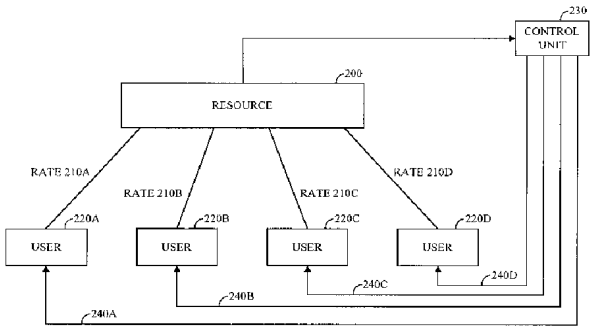
(54) SYSTEME ET PROCEDE DE MODIFICATION DE TAUX D'UTILISATION SUR LA BASE DE VECTEURS DE PERSISTANCE

(54) SYSTEM AND METHOD FOR PERSISTENCE-VECTOR-BASED MODIFICATION OF USAGE RATES

(57)

When a resource of limited capacity is shared by several users, it is possible for the usage rates of the users to exceed the resource's capacity, thereby causing an overload condition. In a system or method according to an embodiment of the invention, at least some of the users have a set of persistence vectors. When an overload condition is detected, the usage rate of at least one of these users is changed, at least in part according to the user's set of persistence vectors.



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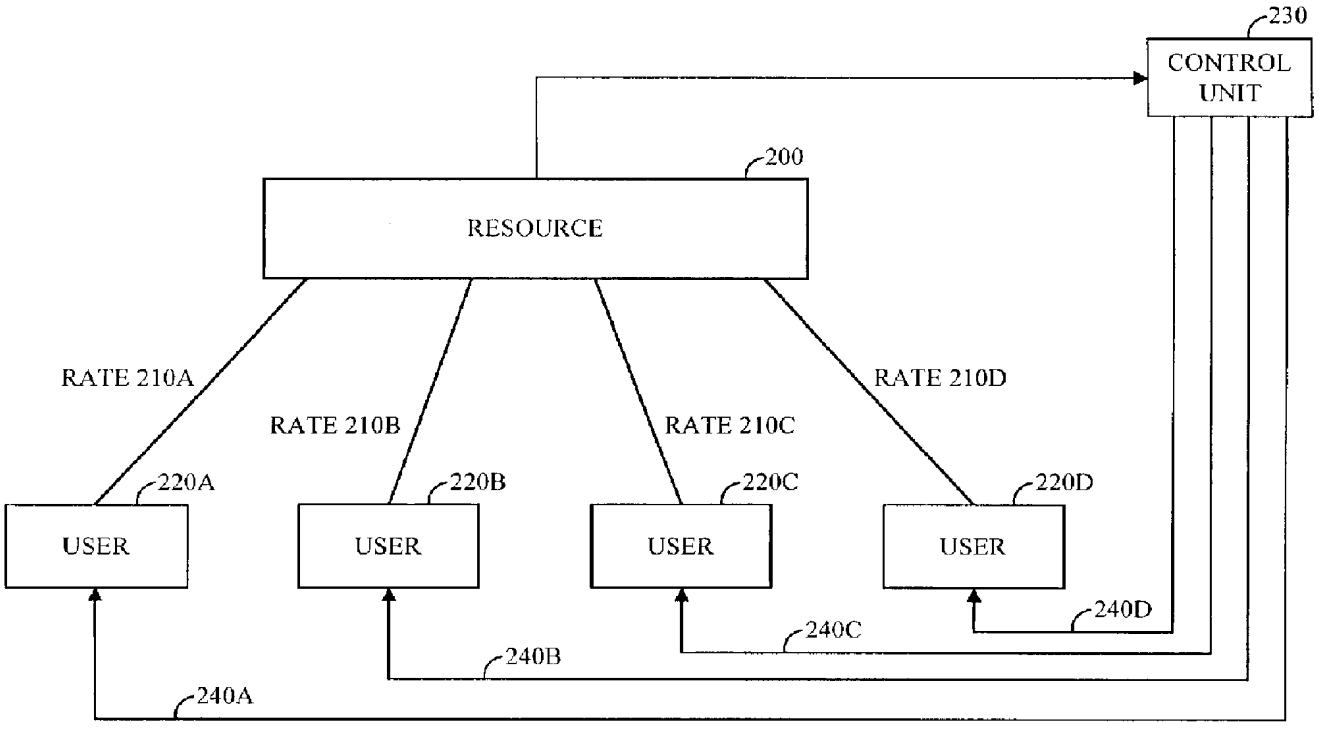

(57) Abrégé/Abstract:
When a resource of limited capacity is shared by several users, it is possible for the usage rates of the users to exceed the resource's capacity, thereby causing an overload condition. In a system or method according to an embodiment of the invention, at least some of the users have a set of persistence vectors. When an overload condition is detected, the usage rate of at least one of these users is changed, at least in part according to the user's set of persistence vectors.

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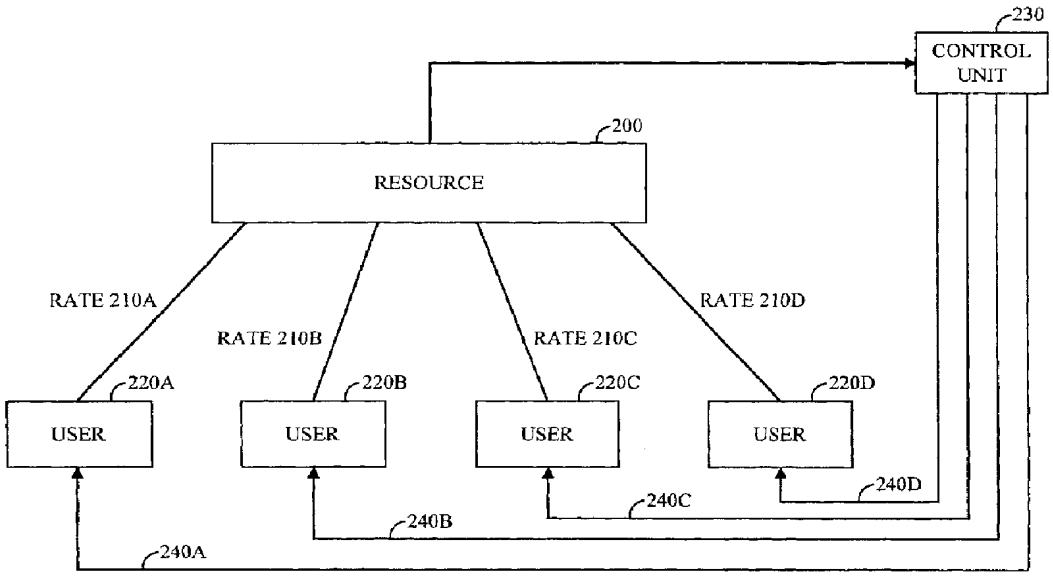
(54) Title: SYSTEM AND METHOD FOR PERSISTENCE-VECTOR-BASED MODIFICATION OF USAGE RATES



(57) Abstract: When a resource of limited capacity is shared by several users, it is possible for the usage rates of the users to exceed the resource's capacity, thereby causing an overload condition. In a system or method according to an embodiment of the invention, at least some of the users have a set of persistence vectors. When an overload condition is detected, the usage rate of at least one of these users is changed, at least in part according to the user's set of persistence vectors.

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

SYSTEM AND METHOD FOR PERSISTENCE-VECTOR–BASED MODIFICATION OF USAGE RATES

BACKGROUND OF THE INVENTION

Field of the Invention

This invention relates to distribution of the use of a limited resource among multiple users. More specifically, this invention relates to the modification of usage rates according to a set of persistence vectors.

Description of Related Art and General Background

A shared resource is one which may be used by multiple users. Shared resources which have limited availabilities or capacities include such diverse examples as electric power stations and other energy plants, water sources such as reservoirs and flowing bodies, supply systems for the distribution of goods and/or materiel, and data communications networks and pathways. Problems associated with allocating the use of a shared resource among multiple users may therefore arise in many different contexts. Regardless of the particular context, however, such resources may be found in many systems in which at least the following conditions hold:

- the capacity or availability of the shared resource may be expressed in terms of a finite rate R of units per measure of time (i.e. kilowatts/hour, gallons/minute, cartons/week, or bits/second);
- at any particular time, the resource is being used by n different users, where n is a nonnegative integer; and
- at any particular time, the usage of the i-th user (where $1 \leq i \leq n$) may be characterized by a finite usage rate u_i of units per measure of time.

A basic model for such a system is shown in FIG. 1, where resource 100 is used by users 120a–d at rates 110a–d, respectively. Depending on the particular implementation, the rate R which characterizes the shared resource may indicate an actual or estimated limit of the capacity of the resource (e.g. in the case of a communications pathway) or, in the alternative, the rate R may be a threshold indicating a maximum safe or permissible load of the resource (e.g. in the case of a power generation facility or device). Likewise, the usage rates u_i may indicate actual use, expected use, or requests or demands for use.

An overload condition arises when the sum of the n usage rates u_i at any one time exceeds the value R. With respect to a power plant, for example, an overload condition may arise when the total current draw exceeds the rated capacity. With respect to a data communications pathway, an overload condition may arise when the total data transfer rate exceeds the pathway's actual capacity, thereby corrupting the data in transmission. In certain situations such as water supply or warehousing of materials, an overload condition may also indicate that although user demands are currently being met, reserve or buffer capacity is being depleted.

Depending on the nature of the resource, the consequences of an overload condition will vary, possibly including the need for an offline period for resource recovery (e.g. cooling of an power generation system or replenishment of a reservoir) or the need to expend present capacity in order to repeat a use that was attempted in the past but failed because of the overload (e.g. retransmission of a data packet corrupted by a collision). The resource may even become temporarily or permanently unable to regain its former capacity. In any case, it is generally desirable to avoid overload conditions whenever possible.

SUMMARY OF THE INVENTION

A system according to an embodiment of the invention includes a resource and a number of users of the resource. Each user of the resource has a usage rate and a set of persistence vectors, and the user's use of the resource is determined at least in part by the user's usage rate. When a predetermined relationship arises between a sum of the usage rates and a certain measure of the capacity of the resource, then at least one of the users changes its usage rate according to at least its set of persistence vectors.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a diagram of a system having a shared resource.

FIG. 2 shows a diagram of a system having a shared resource and a control unit.

FIG. 3 shows a diagram of a system having a consumer, a plurality of producers, and a common channel.

FIG. 4 shows a method according to a first embodiment of the invention.

FIG. 5 shows a method according to a second embodiment of the invention.

FIG. 6 shows a variation of the method of FIG. 5.

FIG. 7 shows an additional variation of the method of FIG. 5.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

When an overload condition arises in a system according to FIG. 1, the users 120 may not be aware that an overload has occurred, especially if the resource is consuming reserve capacity in order to meet user demands. Even if the overload condition causes the resource's availability to a user to drop below a user's expectation or demand, the user may be unable to verify whether the shortcoming is

due to a resource overload or to the failure of another component in the supply path. Moreover, in certain applications such as wireless data communications, it is possible that no feedback mechanism exists whereby a user may obtain timely notification of an overload. Therefore, the user may continue to use the resource, unaware of the problem. In such a situation, it is desirable for the system to include a capability for notifying the users of the overload condition via, e.g., a warning signal.

FIG. 2 shows an example of such a system, wherein control unit 230 receives information related to usage of resource 200 by users 220a–d and sends feedback information such as a warning signal to users 220a–d over respective communications pathways 240a–d. Note that it is possible for control unit 230 to be implemented as a part of resource 200 or alternatively as a part of one of the users 220a–d.

If a user becomes aware of an overload condition, then the possibility exists for user-driven remediation. In this case, if at least some of the users are able to communicate with each other, then a solution such as a reduction in usage rate may be negotiated. In many instances, however, such communication between users may be unavailable, impractical, or otherwise undesirable, in which case an alternate control mechanism may be provided for controlling usage of the resource. This alternate control mechanism may be centralized and/or decentralized.

If complete knowledge of the future usage requirements of the users were available, then it would be theoretically possible to construct an optimal usage schedule that would satisfy the users' requirements as much as possible while completely avoiding all overload conditions. In many practical systems, however, a user's future needs will be unknown even to the user itself. One way to prevent overload conditions in such systems would be on the basis of current usage requirements: for example, by granting usage rate allocations to users only on a

request basis. In order to convey usage requests from the users back to the control unit, however, such a scheme would require an upstream communication pathway which may not otherwise be necessary. Moreover, additional costs and delays are incurred in receiving, processing and responding to such requests.

In order to avoid some of the disadvantages of a request/grant scheme, a decentralized system may be designed wherein control is shared with the users. The control unit in such a system concentrates on the prediction and avoidance of overload conditions while issuing enough feedback information to allow the users to control their own usage to some extent.

A method according to an embodiment of the invention may be implemented in any system that fits the model of FIG. 1 wherein the users may obtain notification of an overload condition (as in the modified system of FIG. 2). An exemplary application of such a system is shown in FIG. 3 wherein users 320a–d are data producers, resource 300 is a common transmission channel linking the producers with data consumer 350, and control unit 330 receives usage information from the consumer. The producers use resource 300 by transmitting data to consumer 350 at or below rates 310a–d, respectively, and they receive respective signals 340a–d (which may include feedback and/or other control information) from the control unit.

One possible implementation of the exemplary application is the reverse link of a CDMA telecommunications system. In this case, each producer may comprise 1) a transmitter, such as a mobile telephone or a WLL (wireless local loop) station, connected to 2) a data-producing device, such as a laptop computer or a point-of-sale terminal, through a PCMCIA card or a similar interface, and outputting data encapsulated in packets over IP or any other suitable protocol. Consumer 350 and control unit 330 may be parts of a base station, and control signals 340 may be carried

over a forward link. Several generations and versions of CDMA telecommunications systems have already been implemented. While most of these CDMA systems have been designed to carry digitized voice communications, however, the method herein described is especially well-suited to a network serving producers with widely varying transmission rates, such as a data-only network or a mixed voice-data network.

A method according to a first embodiment of the invention is described in FIG. 4 with reference to the system of FIG. 2. In this method, a user's use of the resource at any particular time is determined in relation to a predetermined usage rate. As noted in block 400, a particular user is configured to have a usage rate r_j. The usage rate r_j is one among a set of m predetermined available rates r_1 to r_m, where the relation $a < b$ implies that $r_a < r_b$. It is not necessary for all users to have the same set of available rates, but the set for each user should be known to control unit 230 so that it may reliably predict the state of resource use and issue a warning signal appropriately. It is also possible for each user's set of available rates to be updated by control unit 230 whether periodically or otherwise. Schemes of rate selection, assignment, and allocation that may be used in systems incorporating an embodiment of the invention include those described in the copending Patent Applications Nos. 09/264,297, entitled "METHOD OF RATE ALLOCATION IN A DATA COMMUNICATIONS NETWORK," filed March 4, 1999 and assigned to the assignee of the present invention, and, 09/XXX, XXX entitled "METHOD AND APPARATUS FOR PERSISTENCE-VECTOR–BASED RATE ASSIGNMENT," filed concurrently herewith, assigned to the assignee of the present invention, and the disclosure of which application is hereby incorporated by reference.

Note that the usage rate r_j may indicate a maximum allowable rate, i.e. a permission rather than a requirement to use the resource at the given rate. The actual rate at which the user uses the resource may depend upon other factors in addition to the usage rate, such as a user's current need and/or ability to use the resource. Likewise, note that the actual rate at which the user uses the resource need not be a member of the set of available rates.

In one particular implementation, each user has the same fixed set of available rates, wherein each rate is expressed in kilobits per second (Kb/s) and the set of rates is designed to increment in powers of two. Because a doubling in rate requires a doubling in power to maintain the same ratio of energy per bit to noise power spectral density (E_b/N_0), each rate step thus corresponds to a power step of 3 dB. The available rate values in this example include 4.8, 9.6, 19.2, 38.4, 76.8, 153.6, and 307.2 Kb/s.

In addition to a usage rate, each user also has a set of persistence vectors, although it is possible to have other users in the system that lack a set of persistence vectors. The length of each such vector may be any integer greater than zero, and each vector element corresponds to one among the set of available rates and represents a probability that the usage rate will be the corresponding one among the set of available rates. In the exemplary application, each vector element is a persistence value which represents a probability from 0 to 1. The set of persistence vectors may be unique to each user, or the same set may be assigned to all users in a particular class, or the same set may be assigned to all of the users in the system. Likewise, the set of persistence vectors may be a permanent aspect of the operation of the user, or it may be issued by control unit 230, in which case it may be updated periodically or otherwise. Other relevant aspects of persistence vector distribution

and use are discussed in the co-pending Application No. 09/XXX,XXX entitled "METHOD AND APPARATUS FOR PERSISTENCE-VECTOR-BASED RATE ASSIGNMENT," the disclosure of which application is incorporated by reference above.

In this method, the user's set of persistence vectors includes an (m−1)-element vector P, wherein $P = \{P_k \text{ such that } 1 \leq k \leq m-1\}$ and m is the number of members of the user's set of available rates. (The vector P may be the only vector in the set of persistence vectors, or vector P may be selected from among others in the set according to such criteria as the most recent usage rate or the most recent actual rate for this user.) Vector P may (but is not required to) have the form of a probability density function, wherein the sum of its elements (or of the values represented by its elements) is equal or substantially equal to one.

In block 410, the user receives a warning signal from control unit 230. This warning signal may issue, for example, when an actual or impending overload condition is detected, and it may be sent to all users or only to a subset of the users (e.g. only to the users who have persistence vectors). Various embodiments and applications of a system wherein the warning signal is indicated by a busy bit in a reverse link signal are described in co-pending Application No. 09/346,882 entitled "METHOD AND APPARATUS FOR SIGNAL COMBINING IN A HIGH DATA RATE COMMUNICATION SYSTEM," filed July 2, 1999 and assigned to the assignee of the present invention.

Upon receiving the warning signal, the user generates a random number x as indicated in block 420. The range and distribution of x are limited only by the particular implementation; in an exemplary application, x represents a value drawn from a set having a uniform distribution over the range 0 to 1. In block 430, the value

of x is tested against the persistence value P_j, where P_j is the element of persistence vector P that corresponds to usage rate r_j. If the test fails (i.e. x is not less than P_j), then the user's usage rate is not affected by the overload condition, as shown in block 440. If the test succeeds (i.e. x is less than P_j), however, then the user's usage rate is decreased from r_j to r_{j-1}, as shown in block 450. If the user's usage rate is already the lowest rate in the user's set of available rates, then success in block 450 may indicate a reduction to a predetermined lower rate or even a denial of service. This method may be altered to allow the use of one among many other relations between the values of x and P_j in place of the test condition shown in block 430, depending on the particular characteristics of the values chosen for x and P_j.

Note that the values given to the elements of persistence vector P will in part influence how the redistribution of resource usage is biased among users starting with different usage rates. For example, a redistribution which is more equitable may be achieved by choosing large values for elements of persistence vector P which correspond to high usage rates and low values for elements of P which correspond to low usage rates. Such a scheme will make it more likely that a user currently having a high usage rate will reduce its rate, while making it less likely that a user already having a low usage rate will have to reduce its rate any further. Note as well that in a case where each persistence vector is associated with a particular member of the set of available rates, the relations between these vectors will also bias the redistribution of resource usage. Also note that use of the rate doubling scheme described above (or a similar non-constant distribution within the set of usage rates) will allow usage rate reductions by high-rate users to free up more resource capacity than usage rate reductions by low-rate users.

Numerous variations of the method described above may be used in applications of this embodiment. For example, the users may share the same set of persistence vectors, or different sets of persistence vectors may be assigned to allow the implementation of a priority scheme among the users. In another variation, the first element of each persistence vector may be eliminated (or set to represent a probability of 1) so that users already having the lowest usage rate will not suffer a further rate reduction. Likewise, more than one among the first elements of the persistence vectors may be so treated to protect users of other low rates.

Additional constraints on usage rate may exist as consequences of other aspects of the particular implementation. For example, the rate at which the user actually uses or accesses the shared resource may be limited by factors such as the user's present capacity or power. Therefore, it is possible that the user may use or may be permitted to use a rate lower than the usage rate granted by this or a similar method.

It may be desirable to choose rate R (a capacity measure of the shared resource) to be a threshold value rather than the actual capacity of the shared resource so that the warning signal is generated before an overload condition occurs, thereby allowing the system to react to avoid the condition. In this case, the threshold R should be selected to take into account at least (1) the longest possible delay in system response, as characterized by the maximum time between generation of the warning signal and the consequent reduction in total resource usage, and (2) the maximum possible increase in resource usage during the period of such delay.

A method according to a second embodiment of the invention is described in FIG. 5 with reference to FIG. 2. In contrast to the method described above, this method allows the user's usage rate to be reduced to any other rate in the set of

available rates rather than to only one particular rate. As in the method described above, a user is configured to have a usage rate r_j from the user's set of available rates r_1 to r_m (as noted in block 500) and an (m−1)-element persistence vector P which may be selected from a set according to, for example, the index j. In block 510, a warning signal is received from control unit 230, and in block 520 the user generates a random number x as described above. At this stage, the user also sets an index k to be equal to the index j.

In block 530, the value of x is tested against the persistence value P_k, where P_k is the element of persistence vector P that corresponds to usage rate u_k. If the test fails (i.e. x is not less than P_k), then the index j is set to be equal to k in block 560, and the method ends in block 570 with the user being configured to have the usage rate r_j. In this case, in other words, the user's usage rate is not affected by the overload condition.

If the test in block 530 succeeds (i.e. x is less than P_k), then the value of the index k is tested. If k is already at its minimum value (i.e. one in this example), then the procedure continues to blocks 560 and 570 as above. Otherwise, the value of k is decremented (i.e. reduced by one) and the test is repeated. Under this method, when block 570 is finally reached, the user may be configured to have any usage rate in the set which is equal to or less than the usage rate indicated in block 500. Again, this method may be altered to allow the use of one among many other relations between the values of x and P_k in place of the test condition shown in block 530, depending on the particular characteristics of the values chosen for x and P_k.

In a variation of this method as shown in FIG. 6, it is possible for the user to be denied usage of the shared resource. Block 540 is replaced with block 542, which allows the index k to reach a value of zero. When that event occurs, the user is

configured to have a null usage rate in block 580. This null usage rate may represent some predetermined rate outside the set of available rates (e.g. a minimal rate which draws from reserved capacity) or it may represent a usage rate of zero and thus a complete denial of usage. FIG. 7 shows an additional variation of the method of FIG. 5, wherein a new random number x is generated in block 526 at every iteration of the loop (in this variation, block 520 may be reduced as in block 522 to include only the initialization of index k).

With respect to the methods shown in FIGs. 4–7, note that a minimum bound of the selected usage rate may be established by setting elements of the persistence vector which correspond to that rate and to any lesser rates to indicate a probability of 1 (i.e. setting these elements to zero in the examples of FIGs. 4–7). In such a case, the tests in blocks 430 and 530 will fail when that rate is reached (or when the procedure is called with the user already having a lower usage rate), and no further reduction in usage rate will occur.

The foregoing description of the preferred embodiments is provided to enable any person skilled in the art to make or use the present invention. Various modifications to these embodiments are possible, and the generic principles presented herein may be applied to other embodiments as well. For example, indices such as those for the set of available rates and the persistence vector being referenced may begin at zero, or at any other number or symbol, rather than beginning at one. Likewise, in a set of available rates, the relation $a < b$ may imply that $r_a > r_b$, or the various rates may be arranged in some other order instead.

Additionally, the invention may be implemented in part or in whole as hard-wired circuits, as circuit configurations fabricated into application-specific integrated circuits, or as firmware programs loaded into non-volatile storage or software

programs loaded from or into data storage media as machine-readable code, such code being instructions executable by arrays of logic elements such as microprocessors or other digital signal processing units. Thus, the present invention is not intended to be limited to the embodiments shown above but rather is to be accorded the widest scope consistent with the principles and novel features disclosed in any fashion herein.

What is claimed is:

CLAIMS

1. A system comprising:

a resource having a capacity measure; and

a plurality of users, each having a usage rate and a set of persistence vectors,

wherein a use of the resource by each among the plurality of users is determined at least in part by the usage rate of the user; and

wherein when a predetermined relation exists between a sum of the usage rates and the capacity measure, at least one among the plurality of users changes its usage rate according to at least the user's set of persistence vectors.

2. The system according to claim 1, wherein each among the plurality of users has a set of available rates, the user's usage rate being a member of the user's set of available rates.

3. The system according to claim 2, wherein each element of each vector in the set of persistence vectors of each among the plurality of users corresponds to a member of the user's set of available rates; and

wherein each element of each vector in the set of persistence vectors of each among the plurality of users indicates a probability that the user's usage rate will change to be equal to the corresponding member of the user's set of available rates.

4. The system according to claim 3, wherein each vector in the set of persistence vectors of at least one among the plurality of users corresponds to a member of the user's set of available rates.

5. The system according to claim 4, wherein each among the plurality of users has the same set of available rates.

6. The system according to claim 3, wherein the predetermined relation between a sum of the usage rates and the capacity measure exists when the sum of the usage rates is not less than the capacity measure.

7. The system according to claim 3, wherein each among the plurality of users has a random number; and

wherein the usage rate of a user is determined at least in part by a predetermined relation between the random number and at least one of the elements of a vector in the user's set of persistence vectors.

8. The system according to claim 3, wherein each among the plurality of users has a random number; and

when the predetermined relation exists between a sum of the usage rates and the capacity measure, at least one among the plurality of users changes its usage rate according to at least a predetermined relation between the user's random number and a selected element of a vector in the user's set of persistence vectors,

wherein said selected element corresponds to the user's usage rate.

9. The system according to claim 3, wherein each among the plurality of users has a random number; and

when the predetermined relation exists between a sum of the usage rates and the capacity measure, at least one among the plurality of users reduces its usage rate according to at least a predetermined relation between the user's random number and a selected element of a vector in the user's set of persistence vectors,

wherein said selected element corresponds to the user's usage rate.

10. The system according to claim 9, wherein the random number of each among the plurality of users is drawn from a set having a uniform distribution.

11. The system according to claim 9, wherein the predetermined relation between a sum of the usage rates and the capacity measure exists when the sum of the usage rates is not less than the capacity measure.

12. The system according to claim 3, said system further comprising a control unit, wherein the control unit sends a warning signal to at least one among the plurality of users when the predetermined relation exists between a sum of the usage rates and the capacity measure.

13. The system according to claim 12, wherein each among the plurality of users has a random number; and

wherein the usage rate of a user is determined at least in part by a predetermined relation between the random number and at least one of the elements of a vector in the user's set of persistence vectors.

14. The system according to claim 12, wherein each among the plurality of users comprises a data producer, and each among the usage rates comprises a rate of data production.

15. The system according to claim 14, wherein the resource is a wireless channel for data communications; and

wherein use of the resource comprises transmitting data over the wireless channel.

16. The system according to claim 15, wherein the resource is the reverse link of a wireless CDMA channel for data communications.

17. The system according to claim 16, wherein the value of at least one member of a user's set of available rates is substantially equal to $19{,}200 \times 2^i$ bits/second, wherein i is an integer.

18. The system according to claim 15, wherein in the set of available rates of at least one among the plurality of users, the value of at least one member of the set is substantially equal to double the value of another member of the set.

19. The system according to claim 15, wherein the usage rate of at least one among the plurality of users is a null usage rate.

20. The system according to claim 15, wherein an actual use of the resource by at least one among the plurality of users is not greater than the user's usage rate.

21. The system according to claim 15, wherein the control unit modifies the set of persistence vectors of at least one among the plurality of users at least indirectly.

22. The system according to claim 15, wherein the capacity measure is a predetermined threshold, said predetermined threshold being lower than an actual capacity of the resource.

23. The system according to claim 22, the predetermined threshold being determined by at least the actual capacity of the resource, a minimum delay between sending a warning signal and obtaining a resulting reduction in usage of the resource, and a maximum increase in resource usage over a period of the minimum delay.

24. The system according to claim 3, wherein each among the plurality of users has the same set of available rates.

25. The system according to claim 24, wherein each among the plurality of users has the same set of persistence vectors.

26. The system according to claim 25, wherein the predetermined relation between a sum of the usage rates and the capacity measure exists when the sum of the usage rates is not less than the capacity measure.

27. The system according to claim 25, wherein each among the plurality of users has a random number; and

wherein the usage rate of a user is determined at least in part by a predetermined relation between the random number and at least one of the elements of a vector in the user's set of persistence vectors.

28. The system according to claim 25, wherein each among the plurality of users has a random number; and

when the predetermined relation exists between a sum of the usage rates and the capacity measure, at least one among the plurality of users reduces its usage rate according to at least a predetermined relation between the user's random number and a selected element of a vector in the user's set of persistence vectors,

wherein said selected element corresponds to the user's usage rate.

29. The system according to claim 28, wherein the predetermined relation between a sum of the usage rates and the capacity measure exists when the sum of the usage rates is not less than the capacity measure.

30. The system according to claim 29, said system further comprising a control unit, wherein the control unit sends a warning signal to at least one among the plurality of users when the predetermined relation exists between a sum of the usage rates and the capacity measure.

31. The system according to claim 24, said system further comprising a control unit, wherein the control unit sends a warning signal to at least one among the

plurality of users when the predetermined relation exists between a sum of the usage rates and the capacity measure.

32. The system according to claim 31, wherein each among the plurality of users comprises a data producer, and each among the usage rates comprises a rate of data production.

33. The system according to claim 32, wherein the resource is a wireless channel for data communications; and

wherein use of the resource comprises transmitting data over the wireless channel.

34. The system according to claim 33, wherein the resource is the reverse link of a wireless CDMA channel for data communications.

35. A method comprising:

using a shared resource at a rate determined at least in part by a first usage rate;

receiving a warning signal, said warning signal relating to use of the shared resource;

obtaining a random number; and

using the shared resource at a rate determined at least in part by a second usage rate, said second usage rate being determined at least in part by comparing the random number to at least one element of a persistence vector.

36. A data storage medium, said medium bearing machine-readable code, such code being instructions executable by an array of logic elements such as a microprocessor or other digital signal processing unit, said instructions defining a method comprising:

using a shared resource at a rate determined at least in part by a first usage rate;

receiving a warning signal, said warning signal relating to use of the shared resource;

obtaining a random number; and

using the shared resource at a rate determined at least in part by a second usage rate, said second usage rate being determined at least in part by comparing the random number to at least one element of a persistence vector.

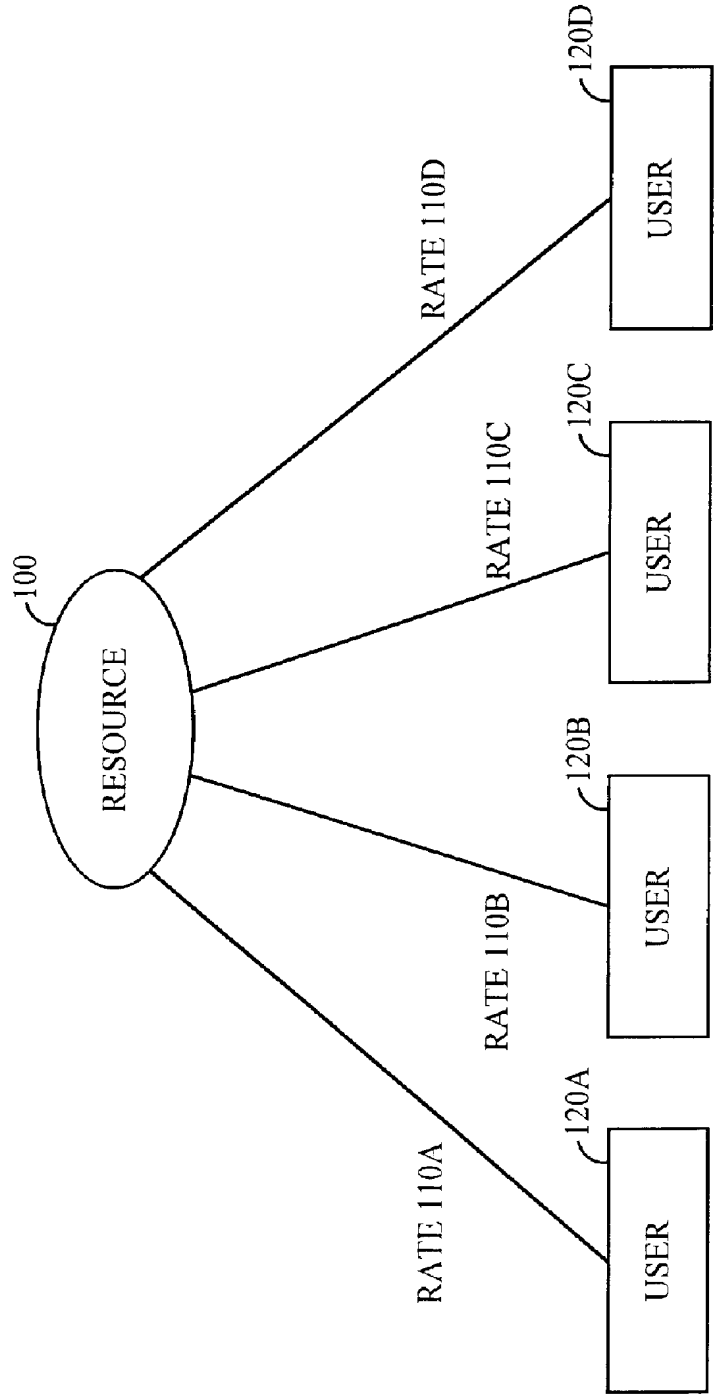
100
RESOURCE
RATE 110A
RATE 110B
RATE 110C
RATE 110D
120A
USER
120B
USER
120C
USER
120D
USER

FIG. 1

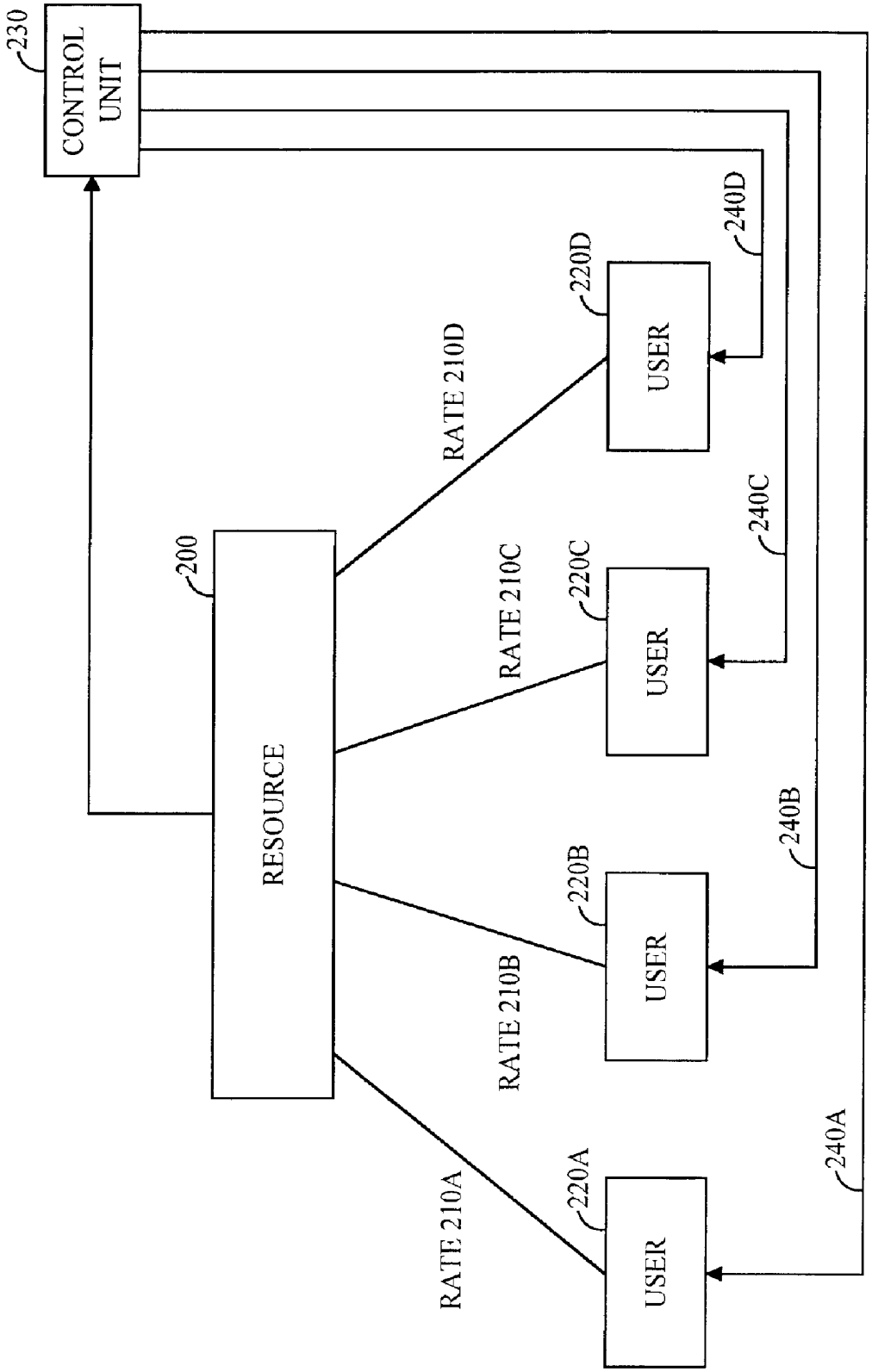
230
CONTROL UNIT
200
RESOURCE
RATE 210D
RATE 210C
RATE 210B
RATE 210A
220D
USER
220C
USER
220B
USER
220A
USER
240D
240C
240B
240A

FIG. 2

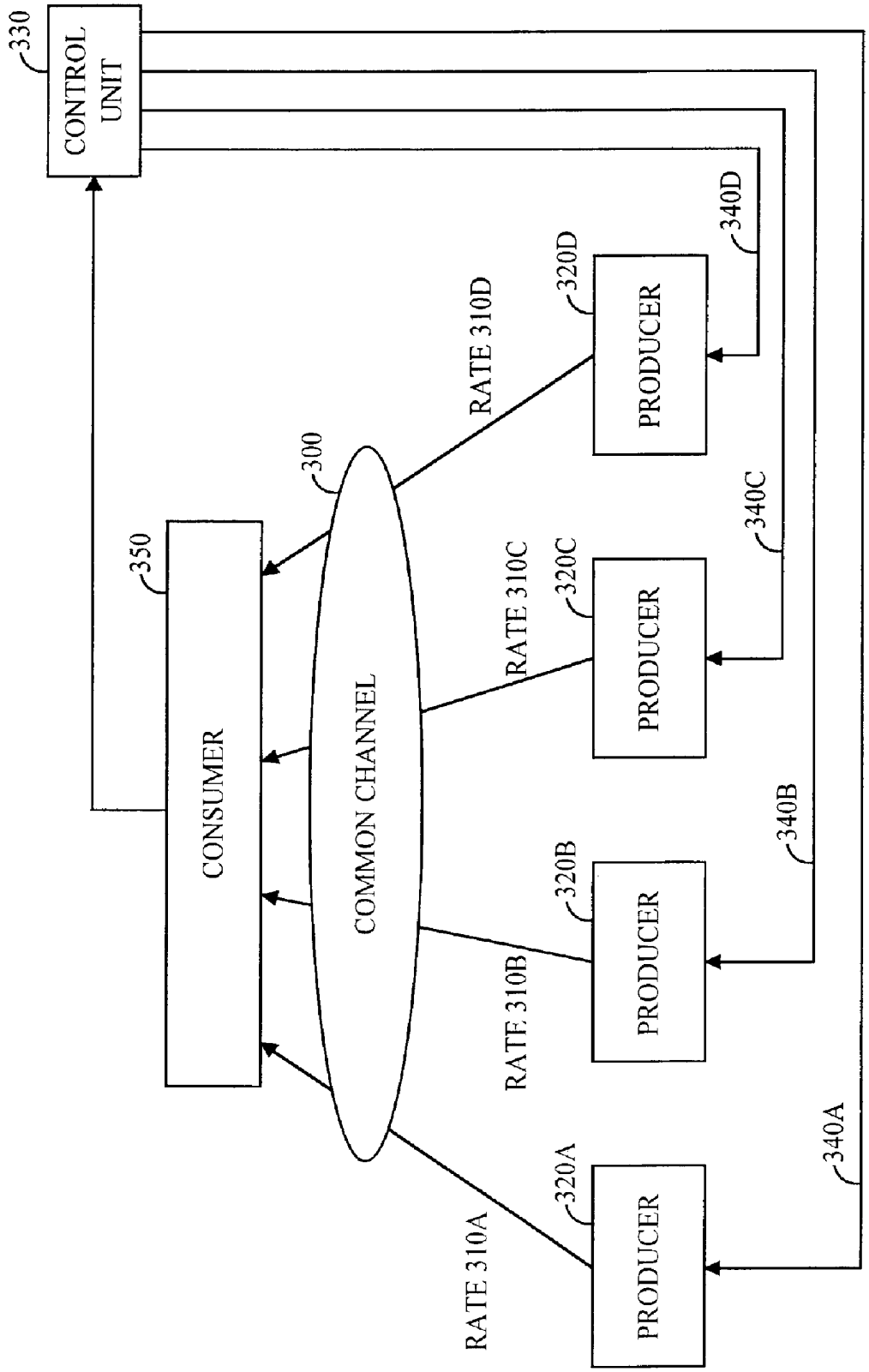
330
CONTROL UNIT
340D
320D
PRODUCER
RATE 310D
300
350
340C
320C
PRODUCER
RATE 310C
CONSUMER
COMMON CHANNEL
340B
320B
PRODUCER
RATE 310B
340A
320A
PRODUCER
RATE 310A

FIG. 3

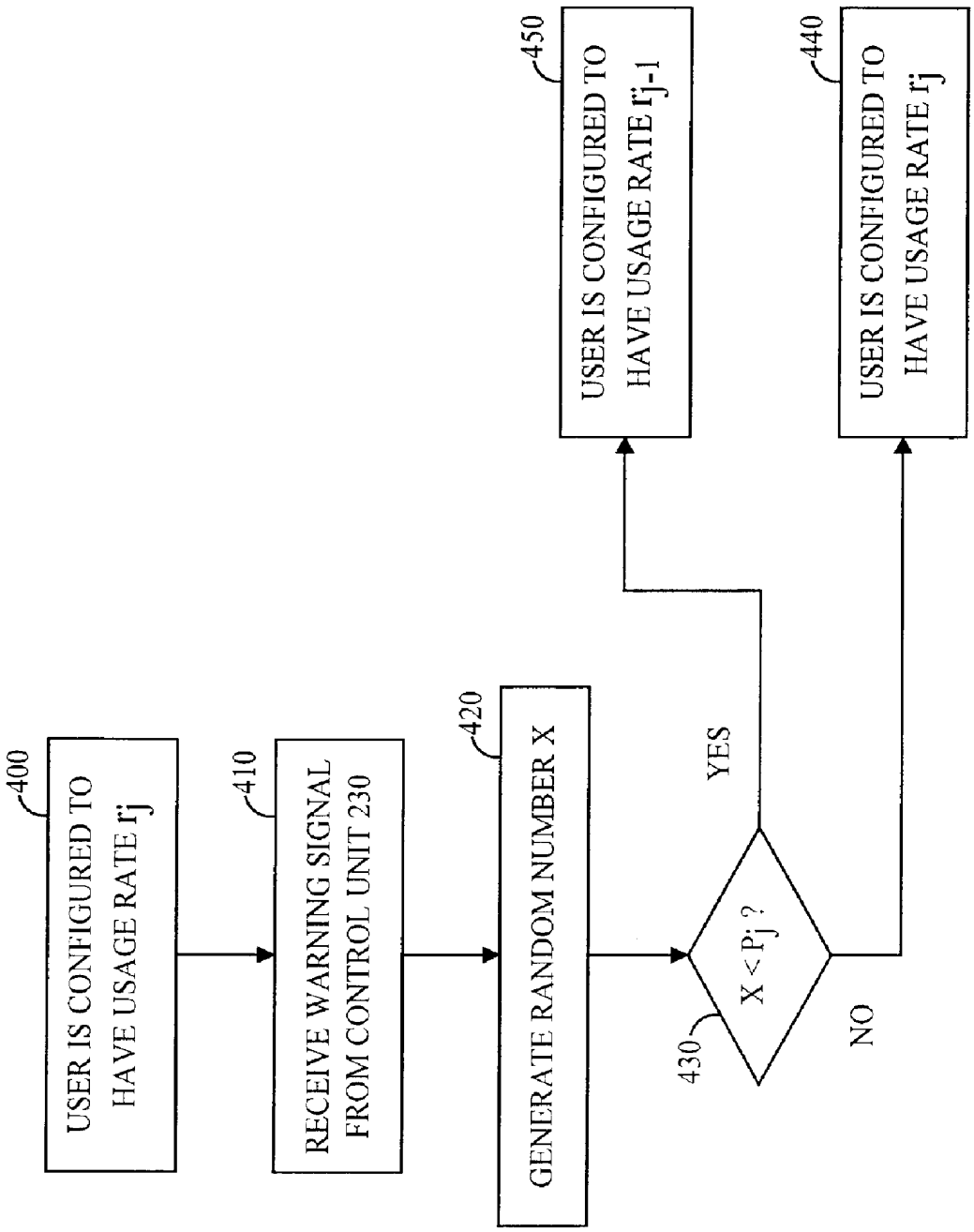
400
USER IS CONFIGURED TO HAVE USAGE RATE rj
410
RECEIVE WARNING SIGNAL FROM CONTROL UNIT 230
420
GENERATE RANDOM NUMBER X
430
X < Pj ?
YES
NO
450
USER IS CONFIGURED TO HAVE USAGE RATE rj-1
440
USER IS CONFIGURED TO HAVE USAGE RATE rj

FIG. 4

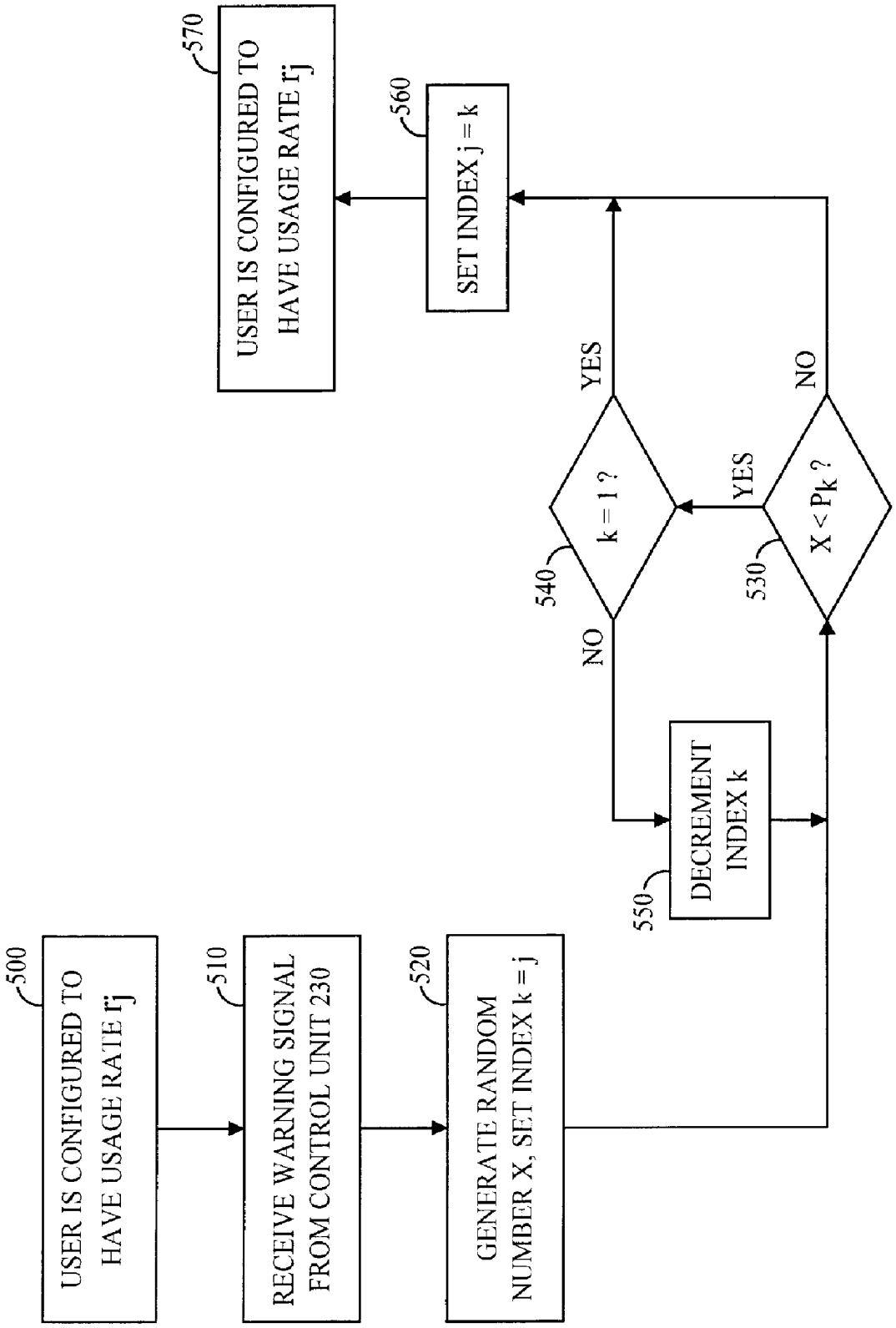
500
USER IS CONFIGURED TO HAVE USAGE RATE rj
510
RECEIVE WARNING SIGNAL FROM CONTROL UNIT 230
520
GENERATE RANDOM NUMBER X, SET INDEX k = j
530
X < Pk ?
YES
NO
540
k = 1 ?
YES
NO
550
DECREMENT INDEX k
560
SET INDEX j = k
570
USER IS CONFIGURED TO HAVE USAGE RATE rj

FIG. 5

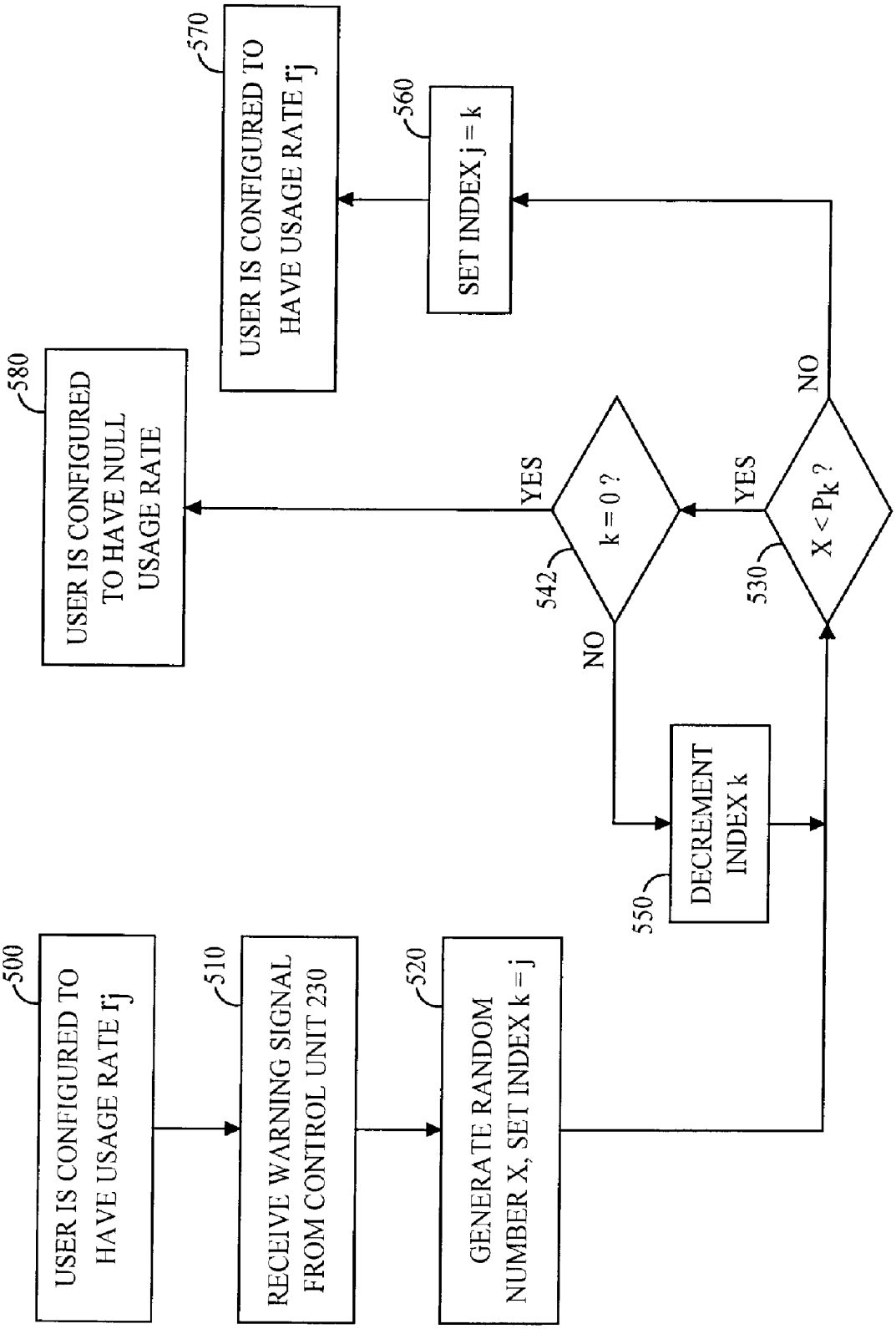
500
USER IS CONFIGURED TO HAVE USAGE RATE rj
510
RECEIVE WARNING SIGNAL FROM CONTROL UNIT 230
520
GENERATE RANDOM NUMBER X, SET INDEX k = j
530
X < Pk ?
YES
NO
542
k = 0 ?
YES
NO
550
DECREMENT INDEX k
560
SET INDEX j = k
570
USER IS CONFIGURED TO HAVE USAGE RATE rj
580
USER IS CONFIGURED TO HAVE NULL USAGE RATE

FIG. 6

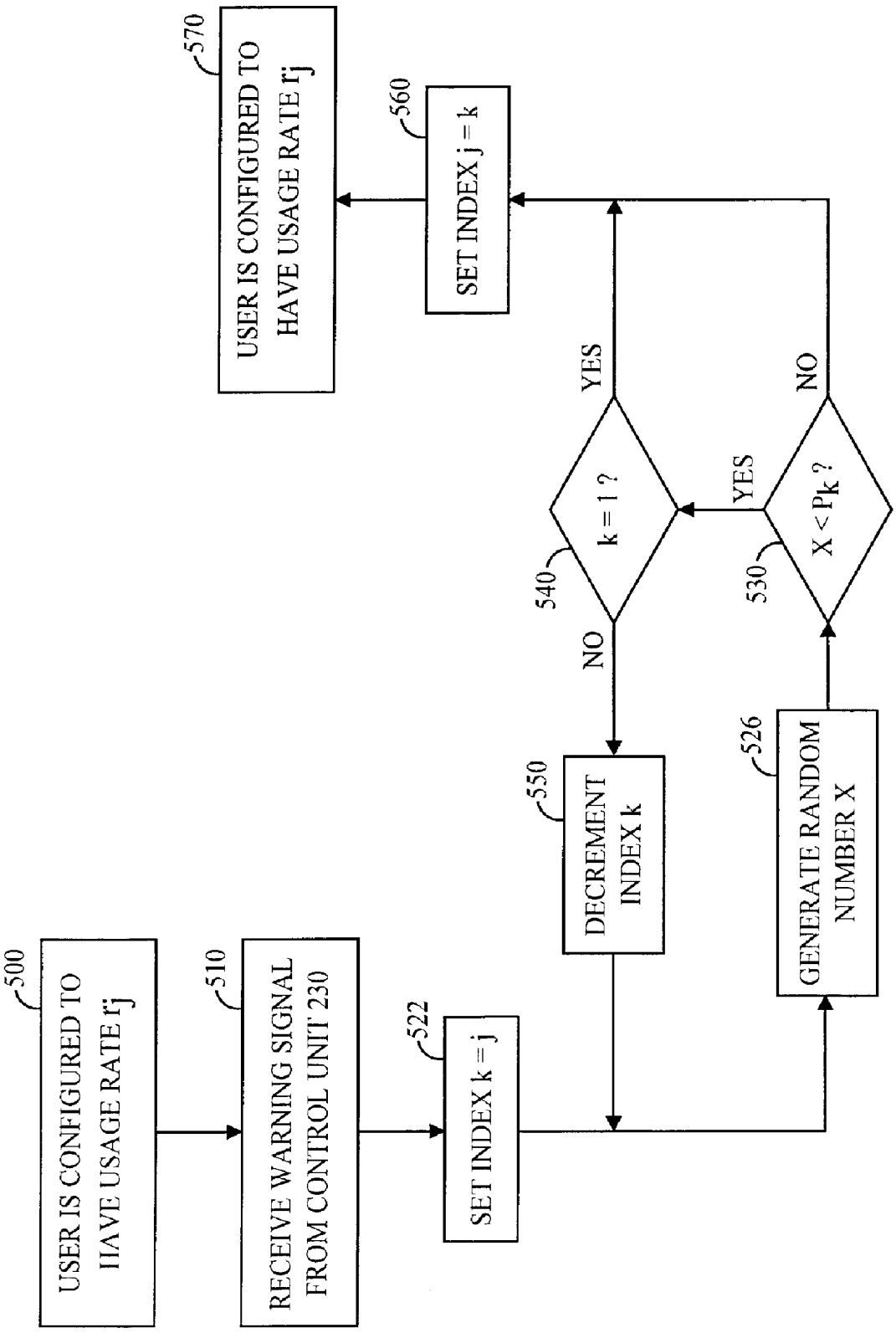
500
USER IS CONFIGURED TO HAVE USAGE RATE rj
510
RECEIVE WARNING SIGNAL FROM CONTROL UNIT 230
522
SET INDEX k = j
550
DECREMENT INDEX k
526
GENERATE RANDOM NUMBER X
540
k = 1 ?
530
X < Pk ?
YES
NO
YES
NO
560
SET INDEX j = k
570
USER IS CONFIGURED TO HAVE USAGE RATE rj

FIG. 7